

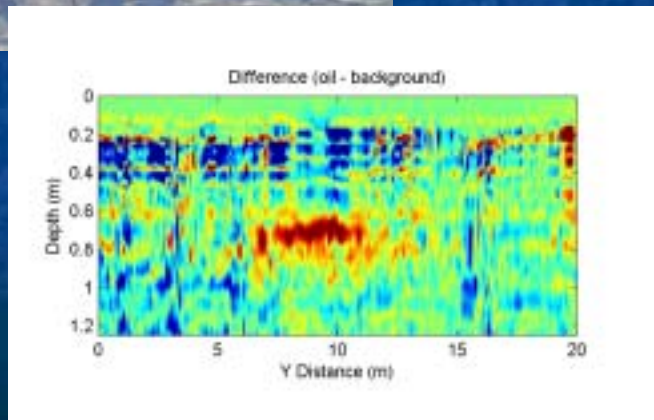
Developments with Ground Penetrating Radar to Detect and Map Oil Trapped Under Ice



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Boise State University*

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Per Johan Brandvik, SINTEF



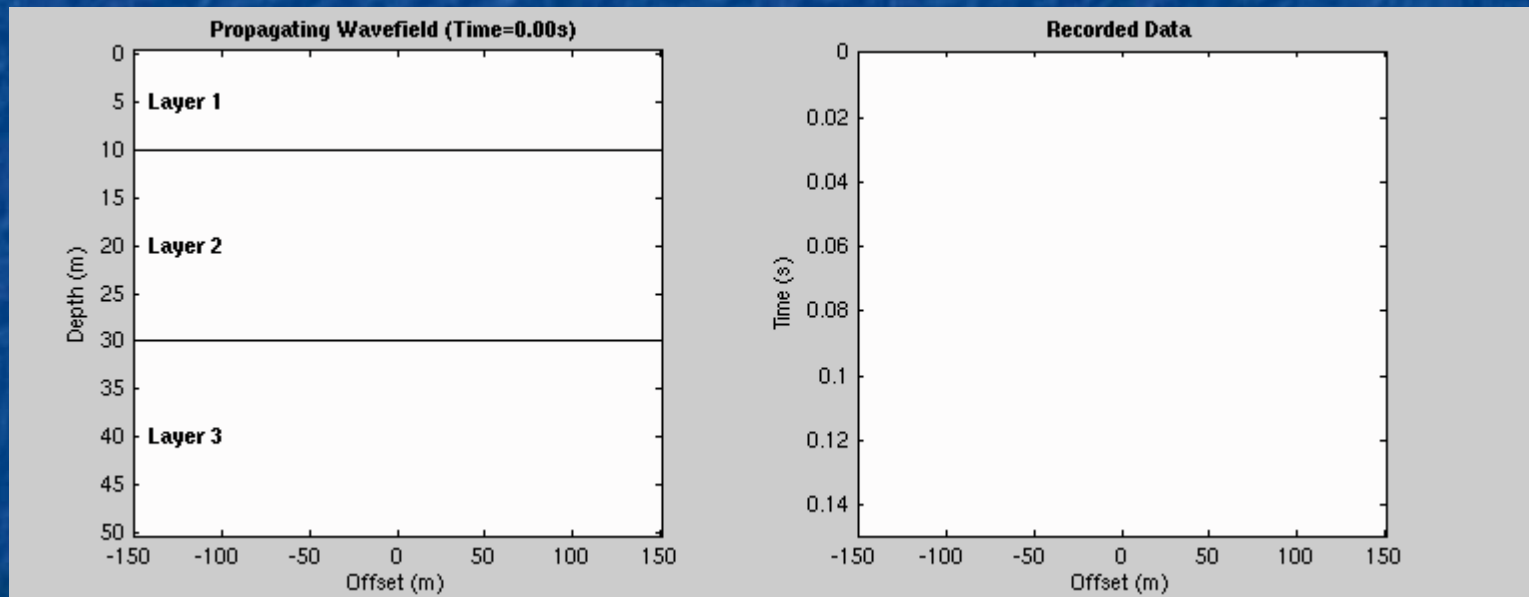
Acknowledgements

- Minerals Management Service
- Alaska Clean Seas
- Statoil
- Alaska Department of Environmental Conservation
- Exxon Mobil
- Conoco Phillips
- SINTEF Staff
- Len Zabilansky – US Army Cold Regions Research and Engineering Laboratory
- BSU graduate students Troy Brosten, Scott Hess, and Leah Steinbronn

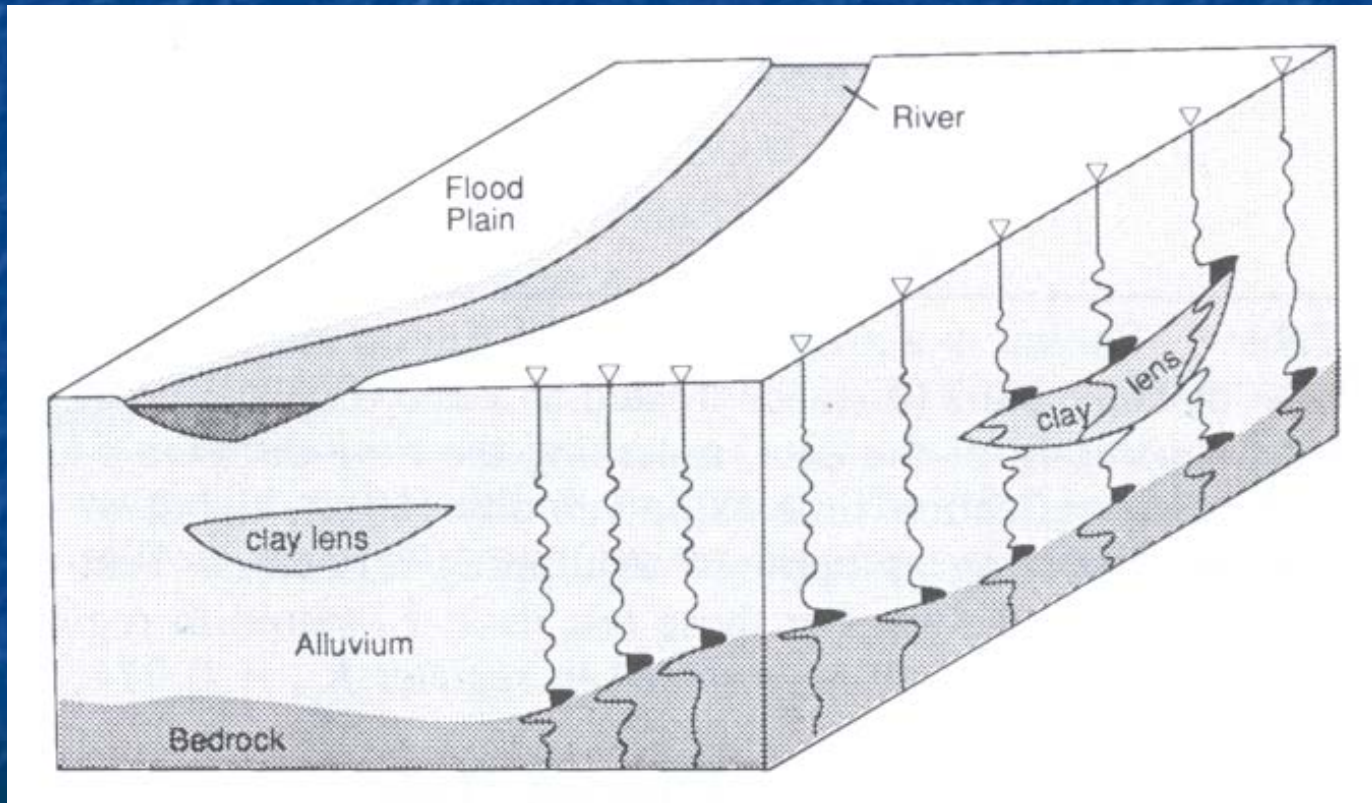
Fundamentals of Ground Penetrating Radar

- GPR is an electromagnetic wave operating at radio frequencies
 - 10 MHz – 1 GHz
- Sensitive to changes in electrical properties
 - Electric permittivity
 - Electric conductivity
 - Signal won't propagate through good conductors

Recording the Reflected Waves



Conceptual Model of the GPR Method

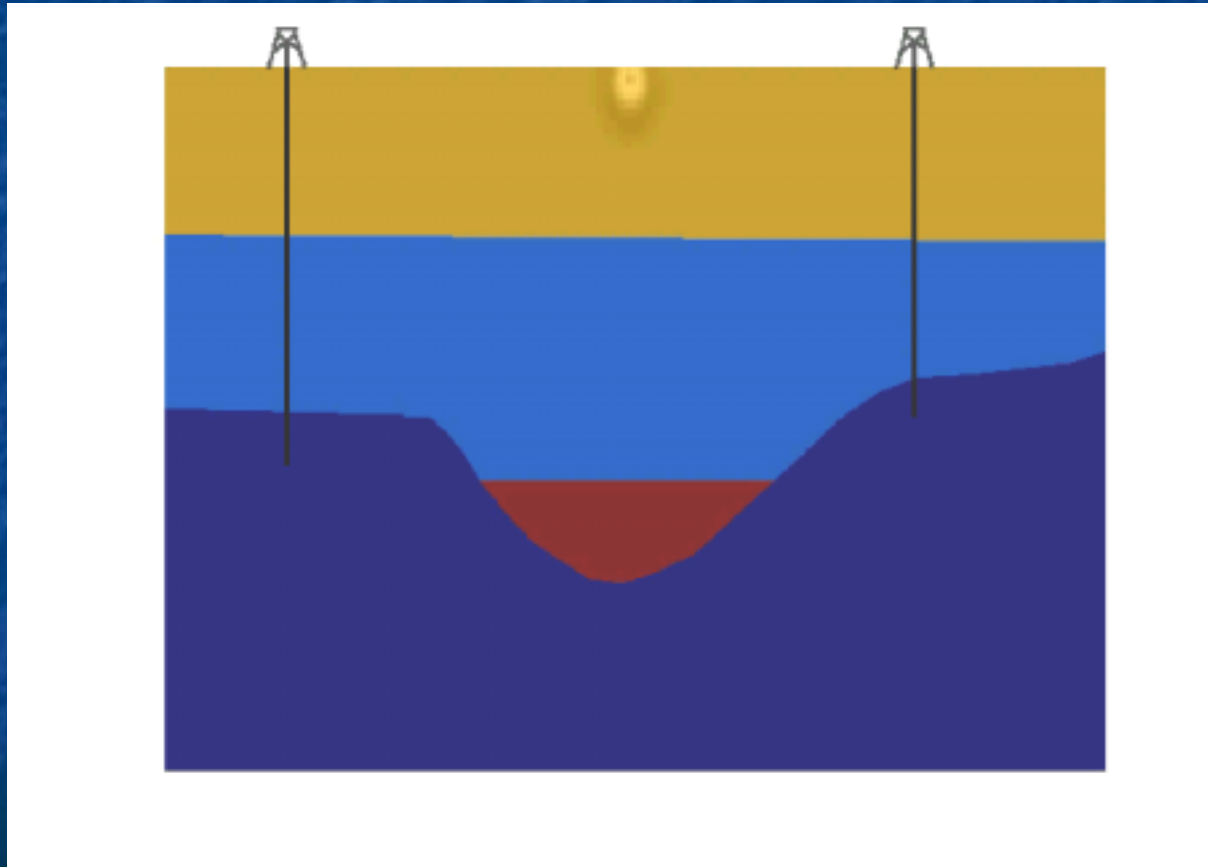


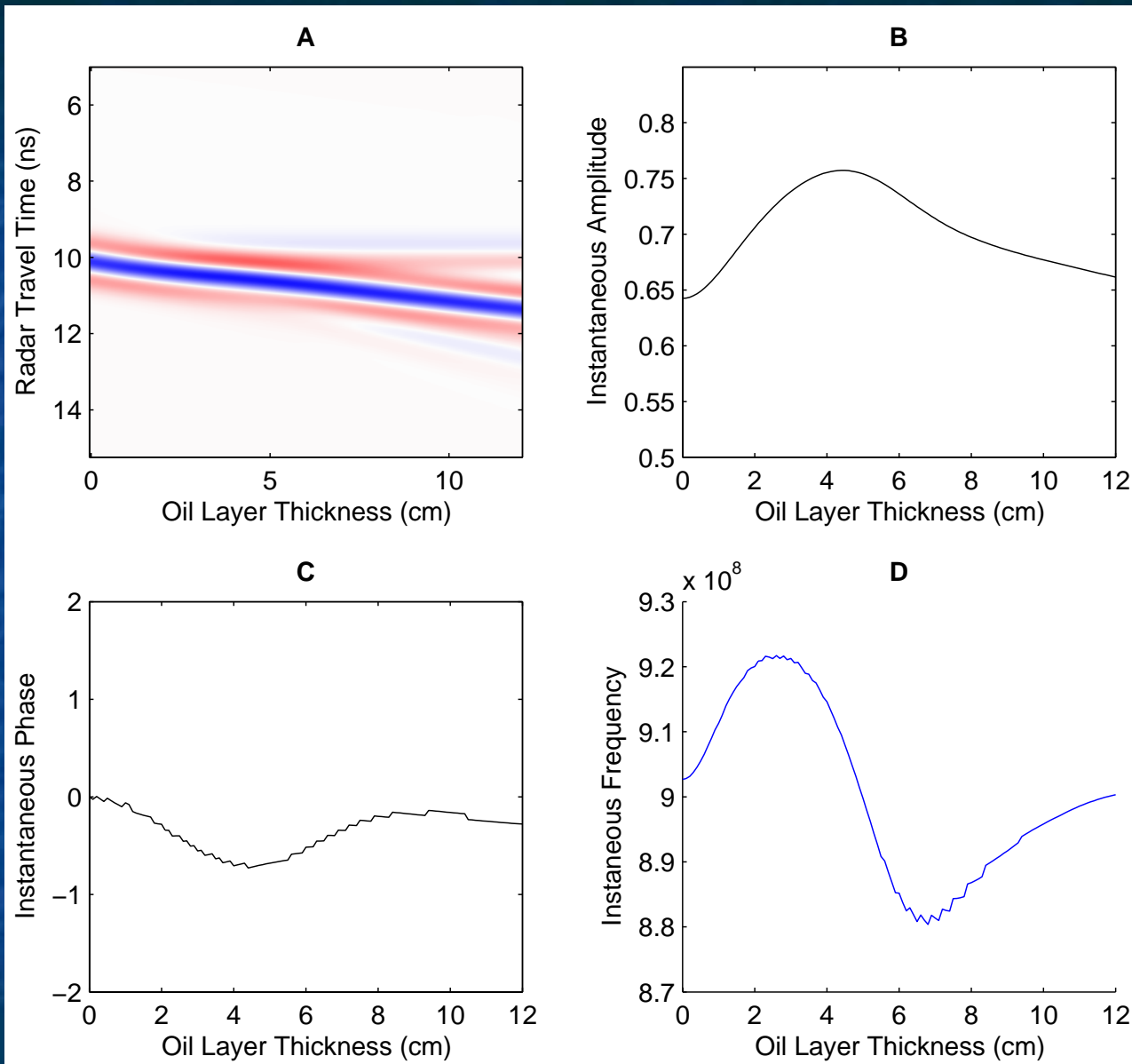
From Steeples and Miller, 1992

Electrical Properties in the Arctic Marine Environment

Material	Relative Dielectric Permittivity	Conductivity (S/m)	Velocity m/ns	Wavelength @ 500 MHz
Air	1	0	0.3	60 cm
Sea Water	88	1-5	No propagation	
Sea Ice	4-8	.01 - .1	.134	27 cm
Oil	2	.0005	.212	42 cm

Electromagnetic Wave Propagation





Suggested by Goodman, Dean and Fingas in 1985!

THE LEADING EDGE

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Special Section:

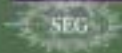
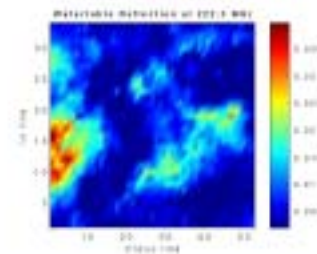
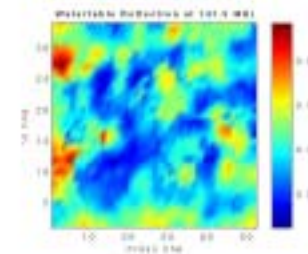
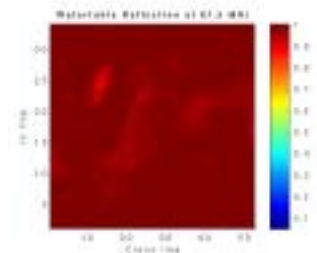
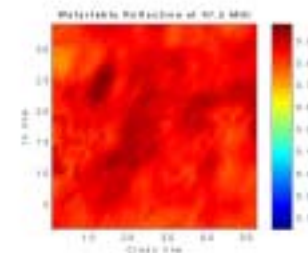
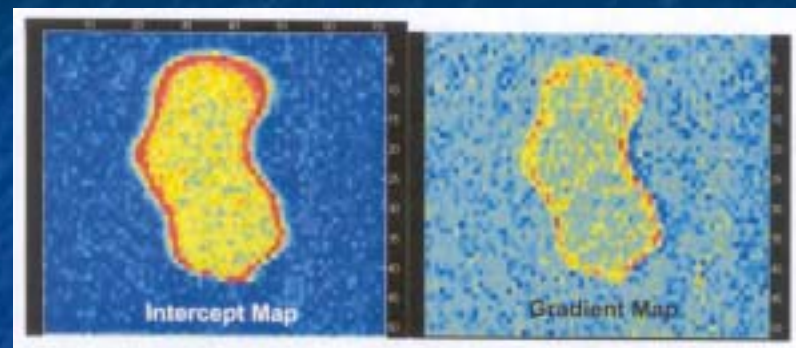
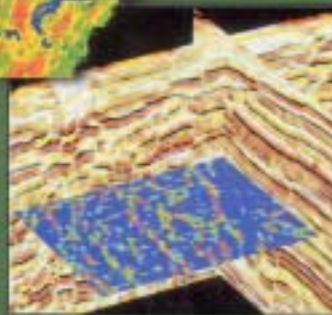
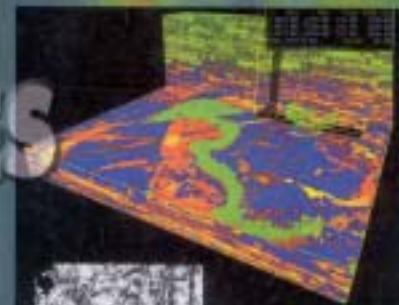
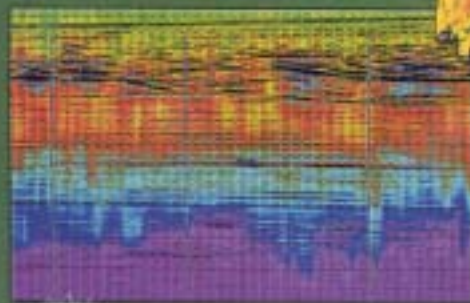
ATTRIBUTES

Interpreters' Corner:

Depth conversion of Tangguh gas fields

The Meter Reader:

Remote sensing of hydrocarbon layers by seabed logging (SBL): Results from a cruise offshore Angola

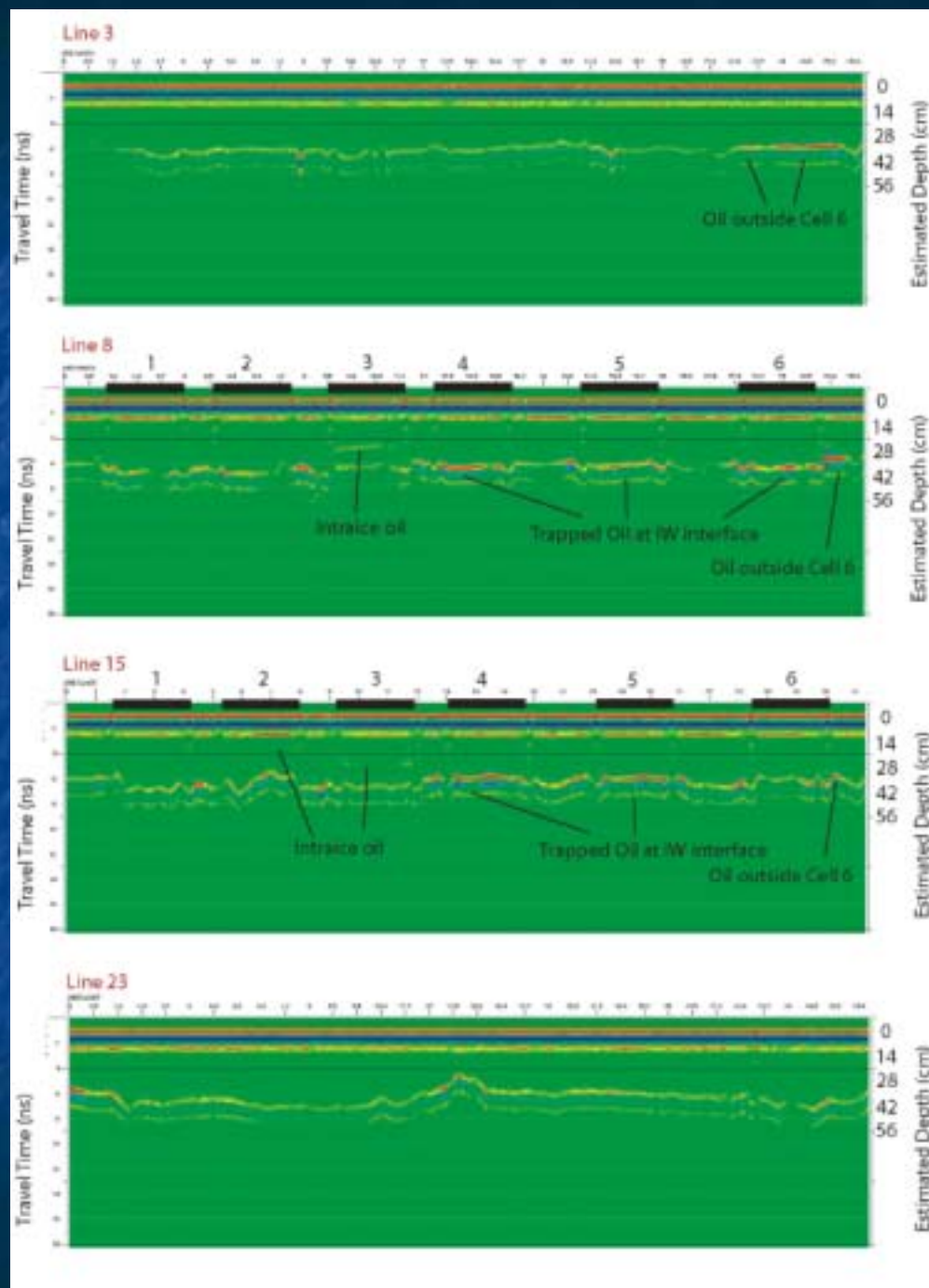


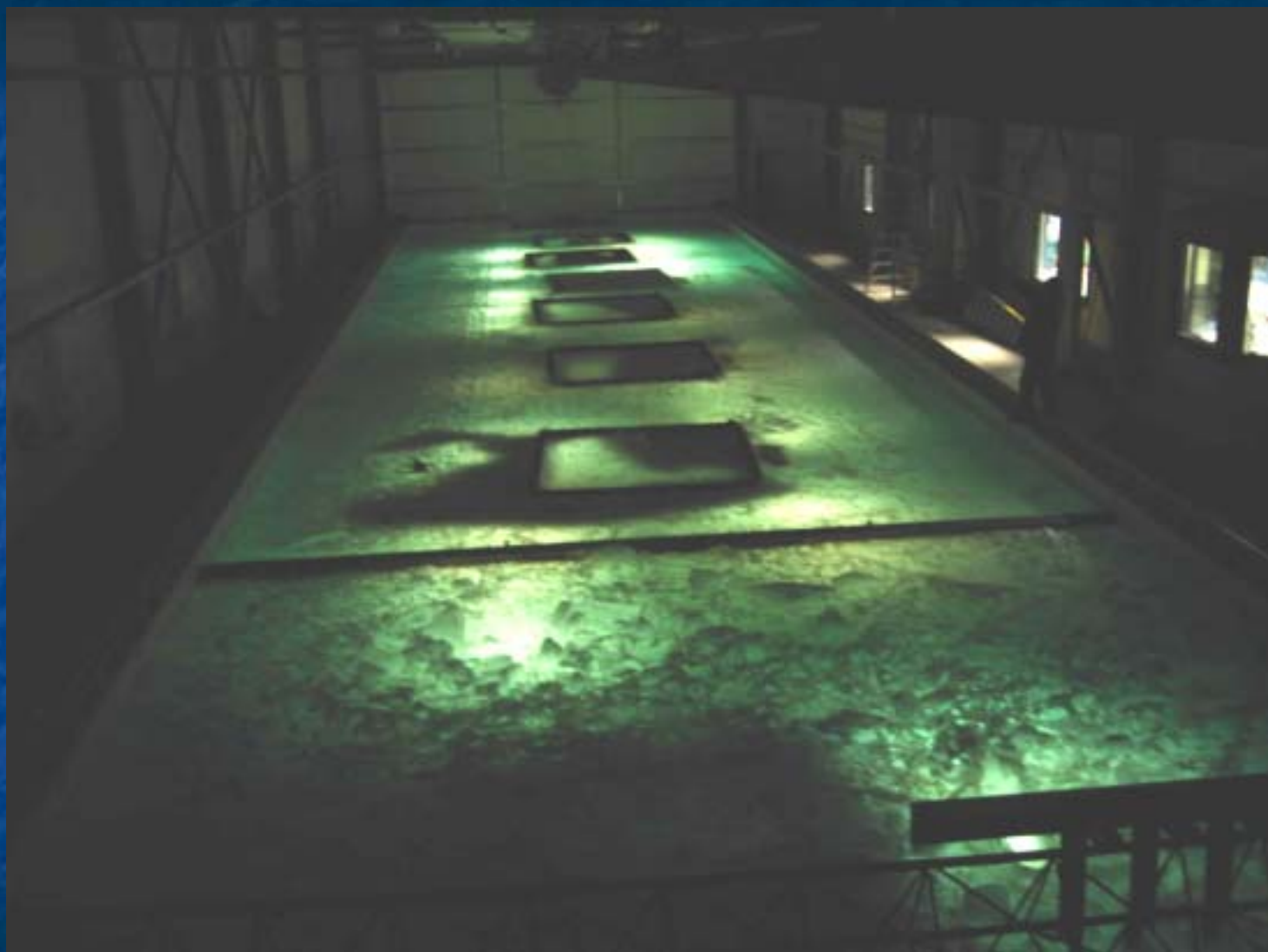
THE SOCIETY OF EXPLORATION GEOPHYSICISTS
609.1070-8834

Controlled Experiment Design

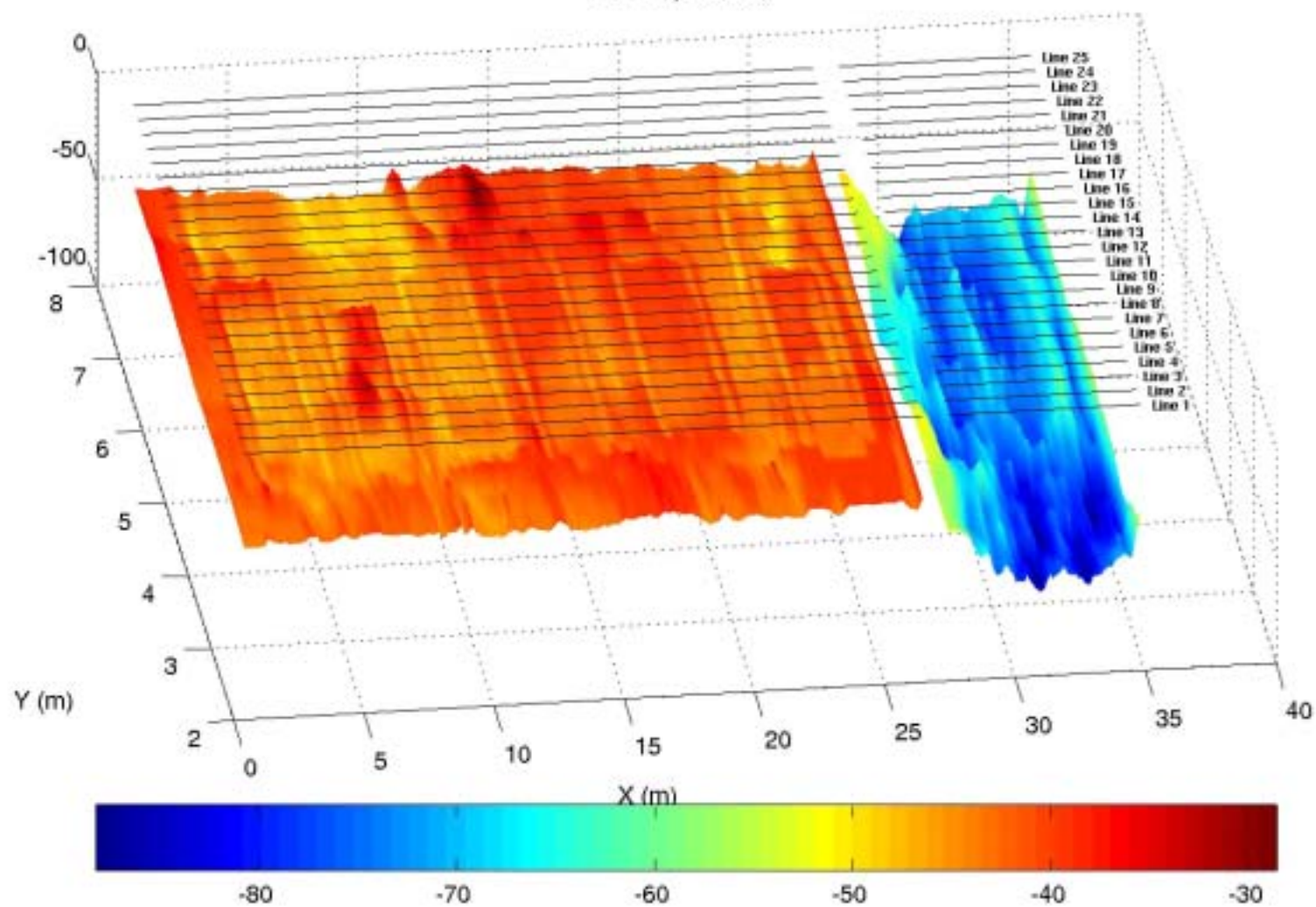
- Cold Regions Research and Engineering Lab
- 9 m x 40 m cold pool
- 7, 2x2 m isolated test cells
- 35 cm ice thickness





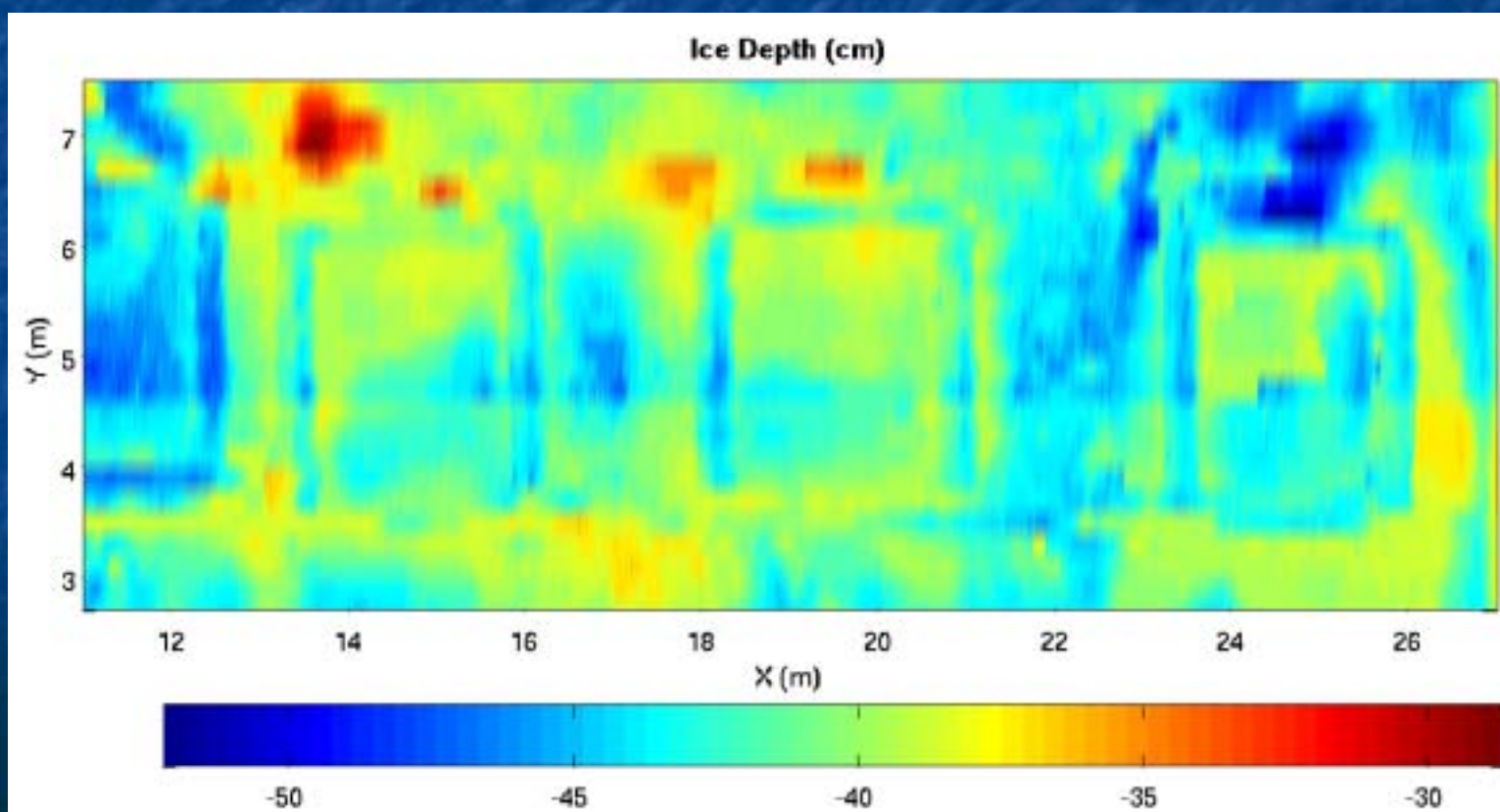
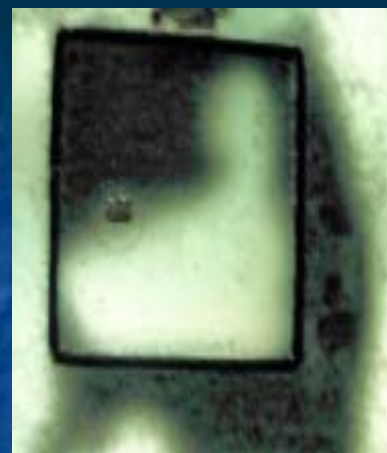


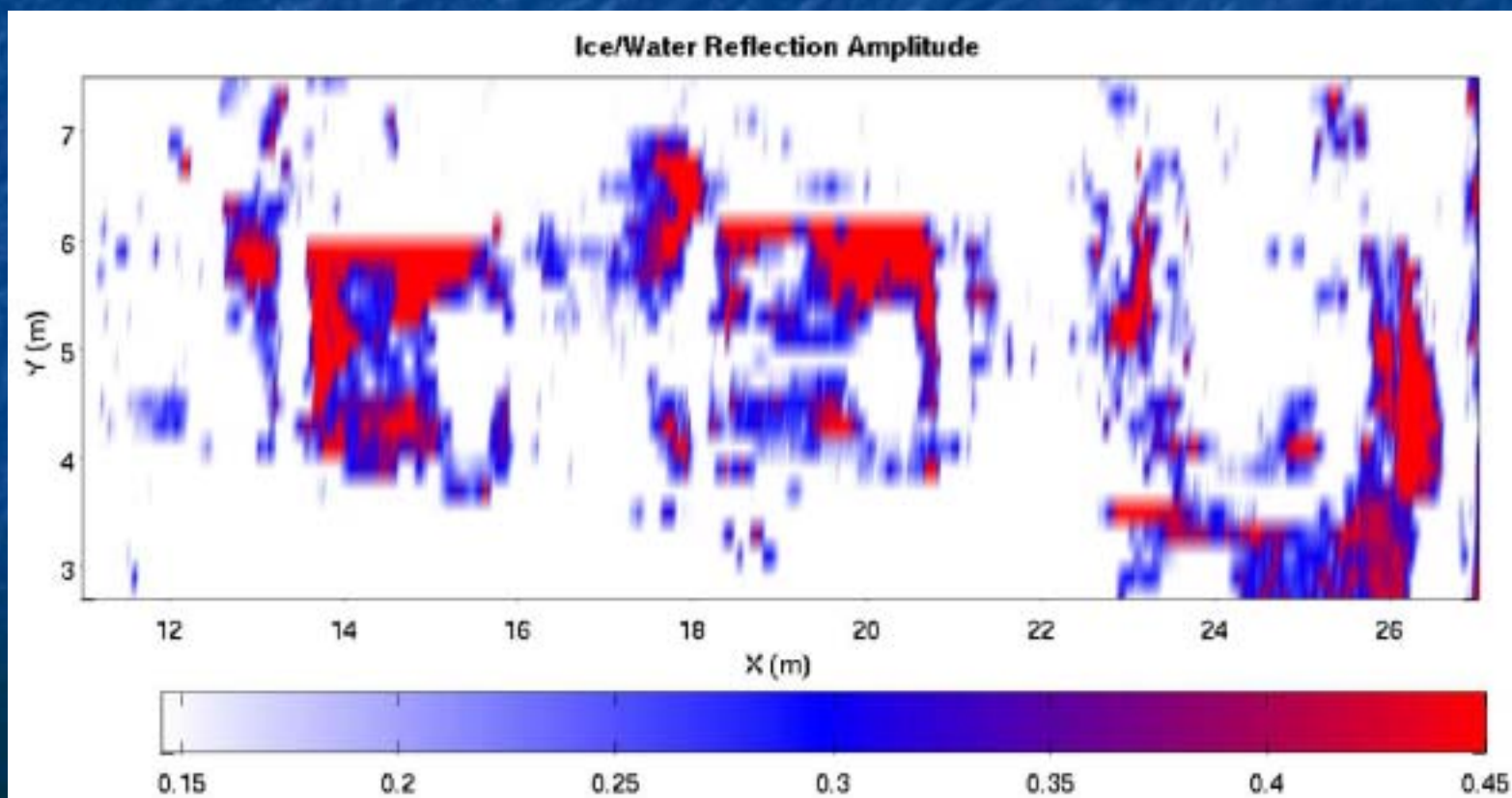
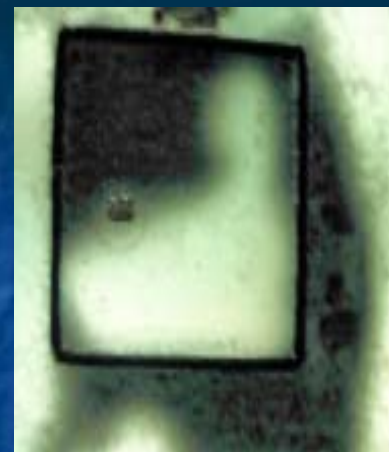
Ice Depth (cm)

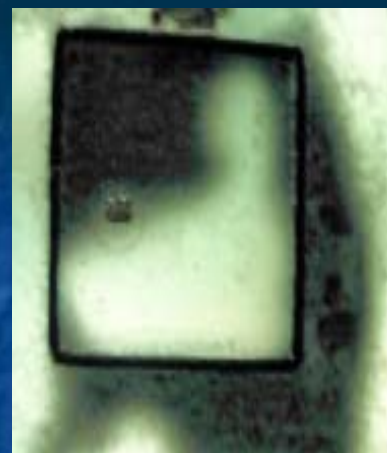




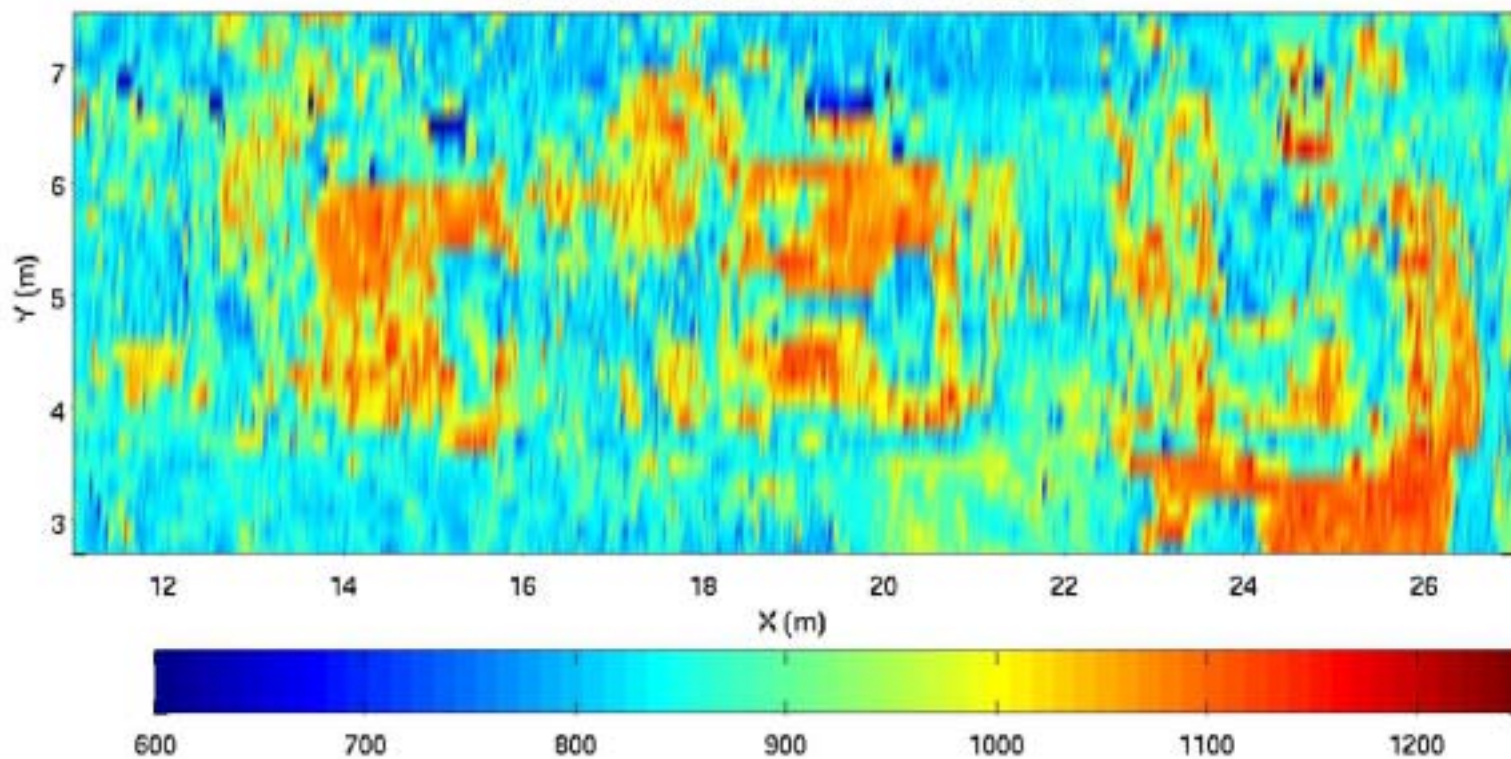


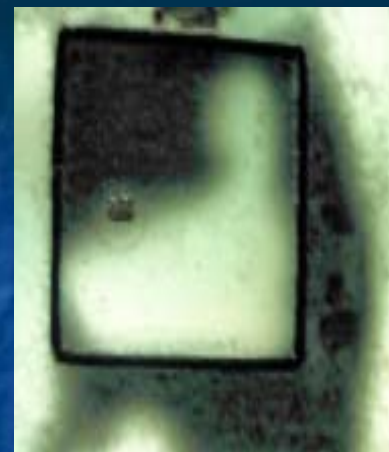




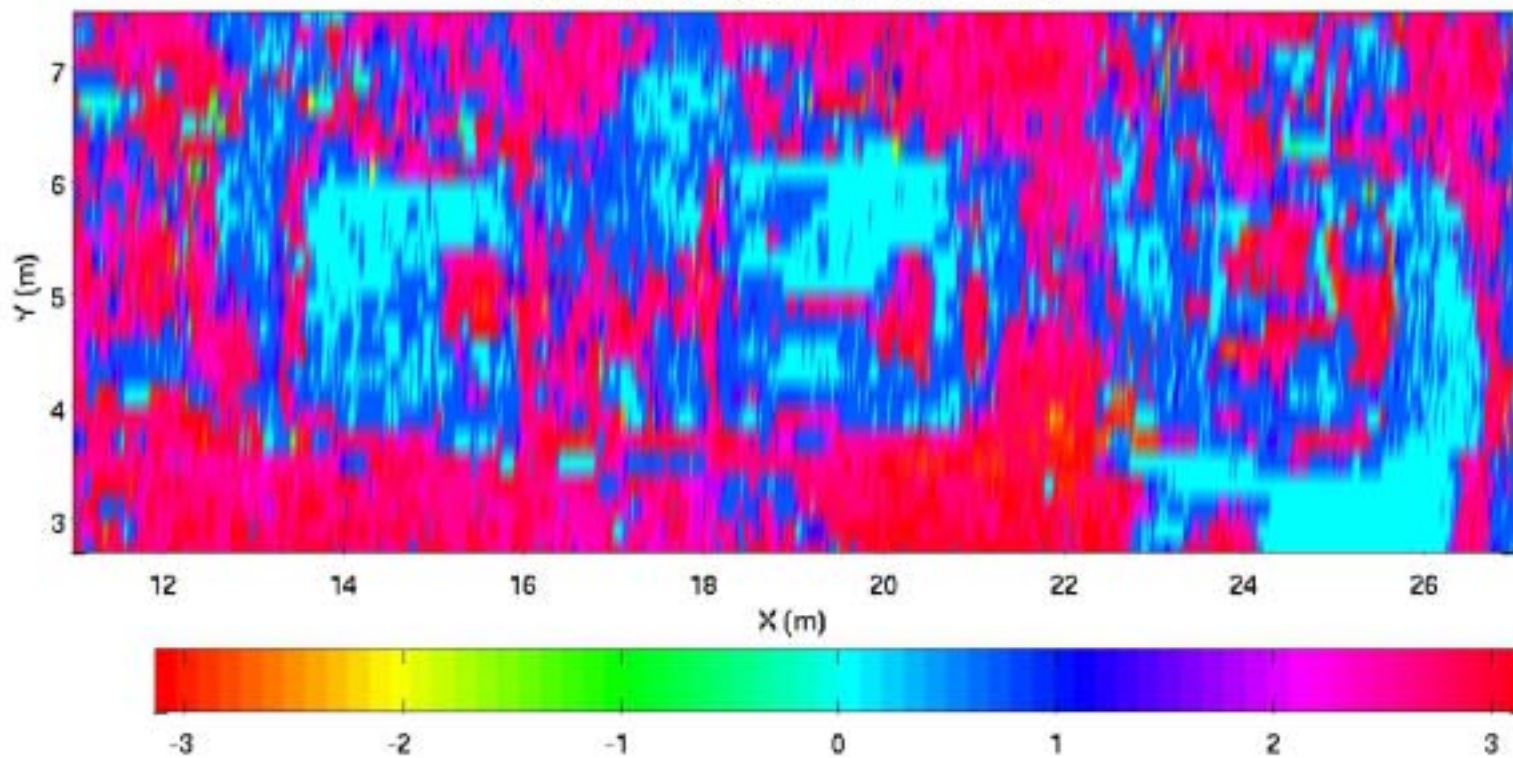


Ice/Water Reflection Instaneous Frequency





Ice/Water Reflection Instantaneous Phase



Surface Ocean Currents



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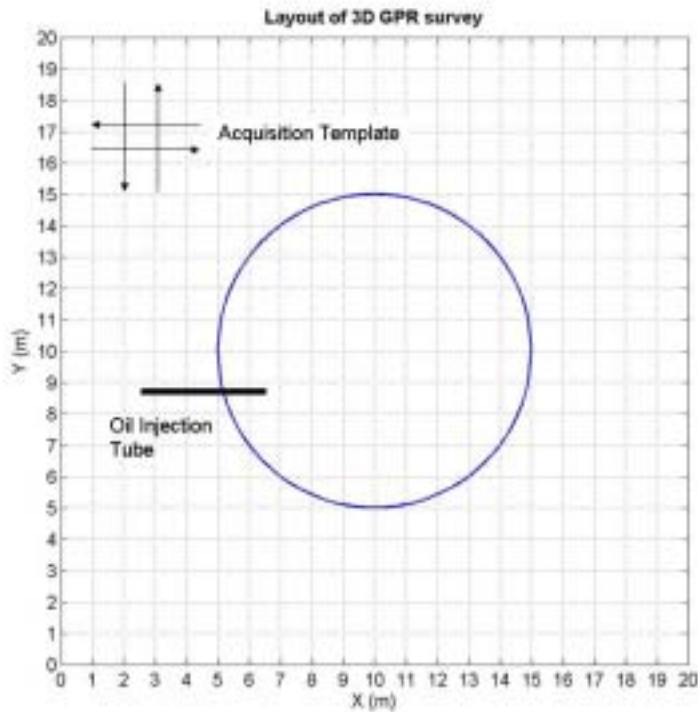


Controlled spill conducted in an 11 m diameter containment cell constructed by SINTEF personnel. Plastic containment skirt extends to 1.5 m

Spill consisted of 3400 l of Statfjord crude pumped into the cell over a period of 2 hr

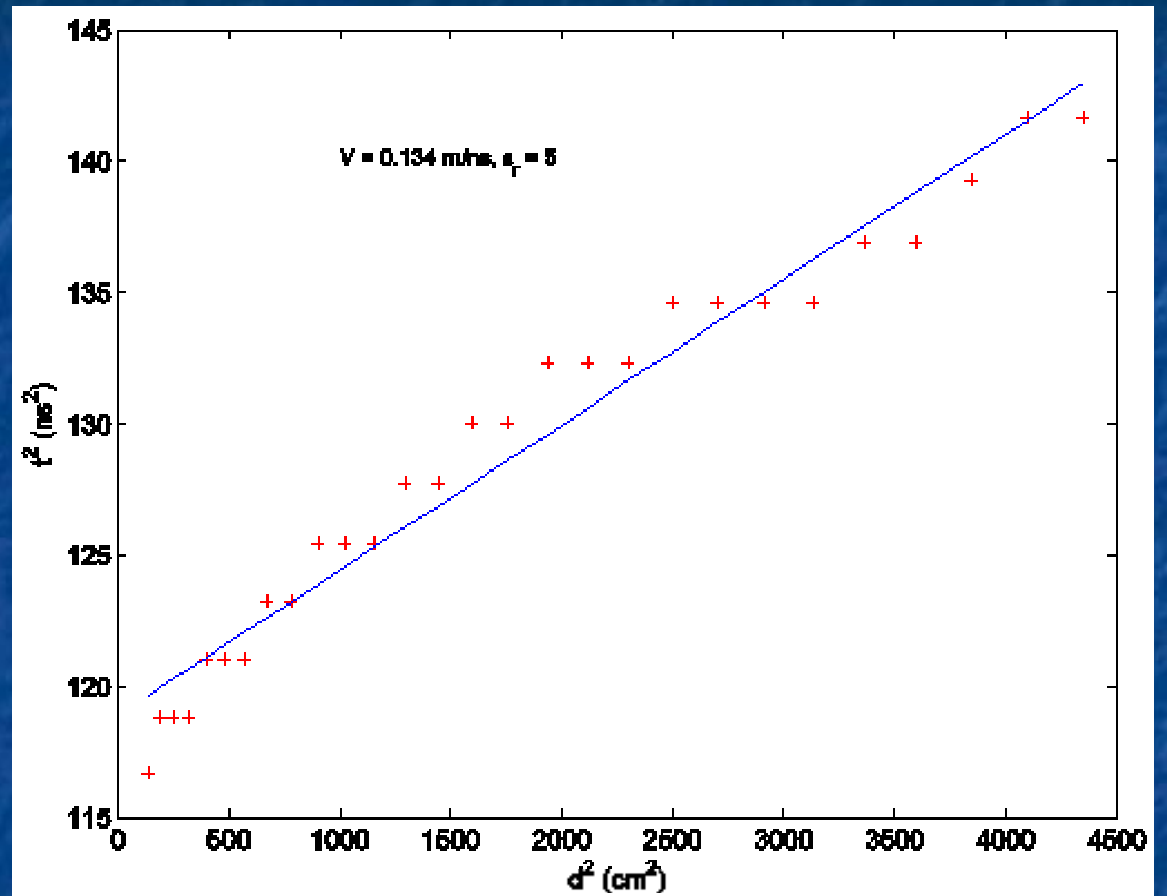
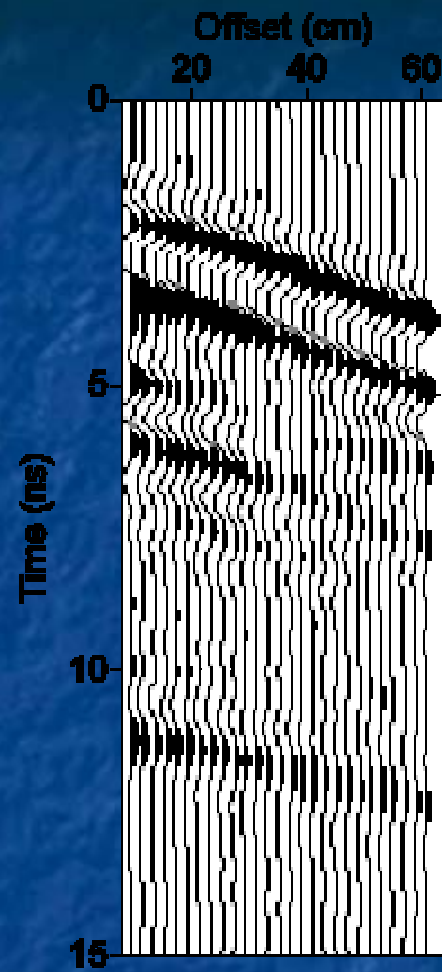


GPR Data Acquisition

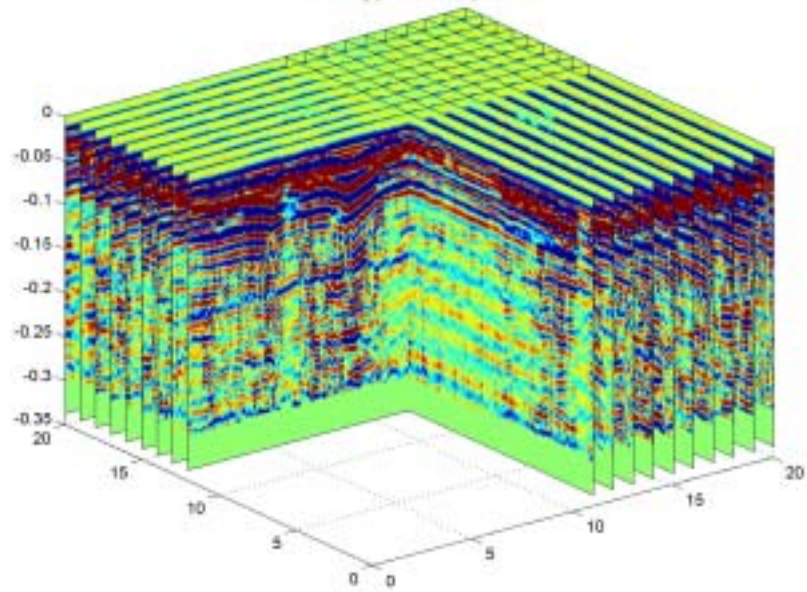


- All data acquired with Pulse Ekko Pro GPR system w/ 500 and 1000 MHz antennas
- Multi-offset acquisition to determine effective permittivity of ice
- Pre and post oil emplacement 3D surveying over 20 x 20 m grid
- Large scale 2D profiling
- Airborne tests

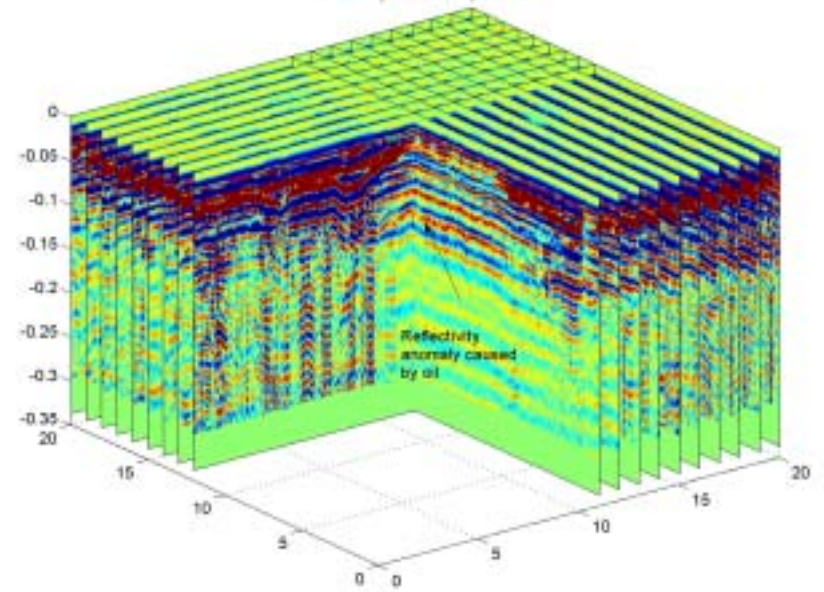


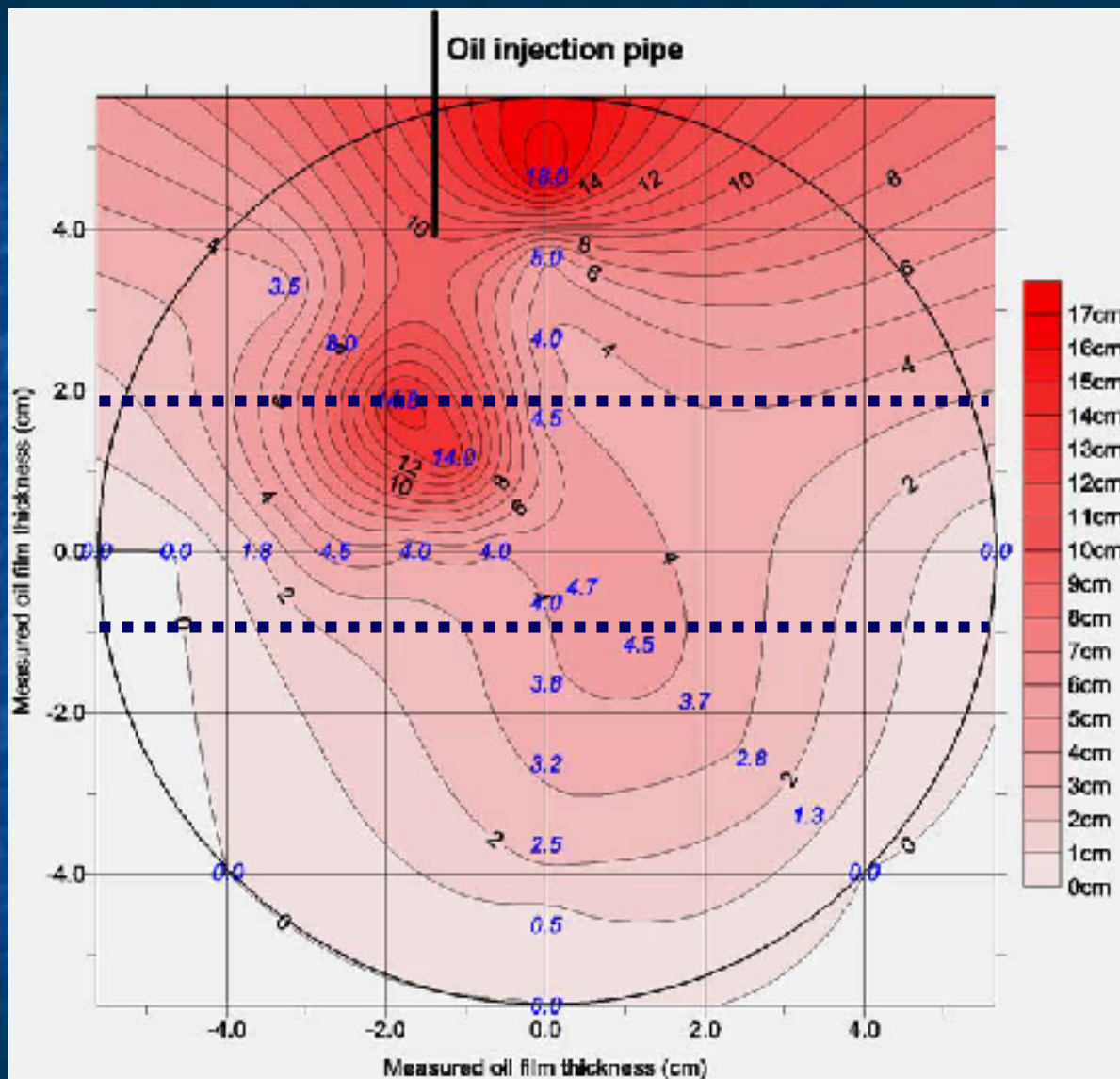


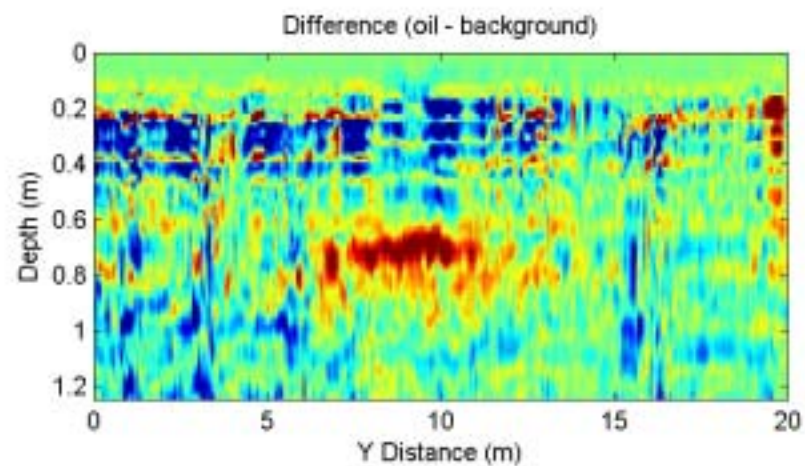
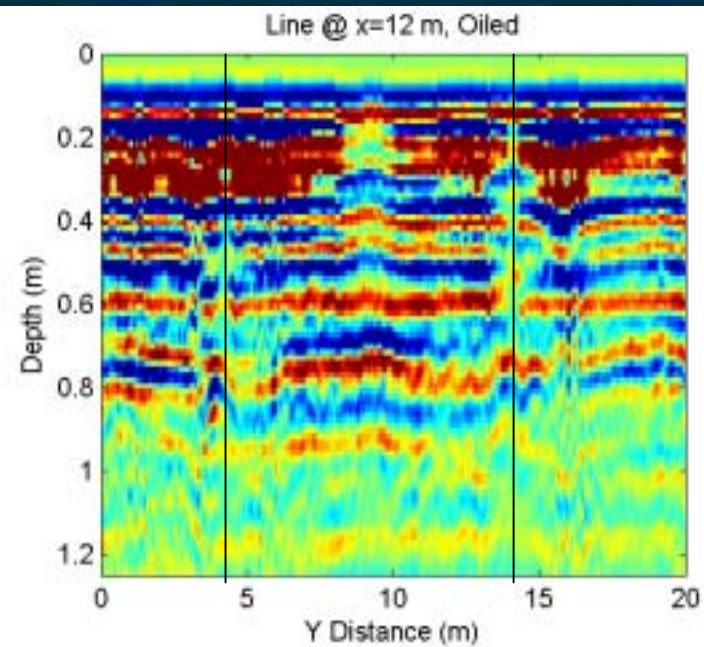
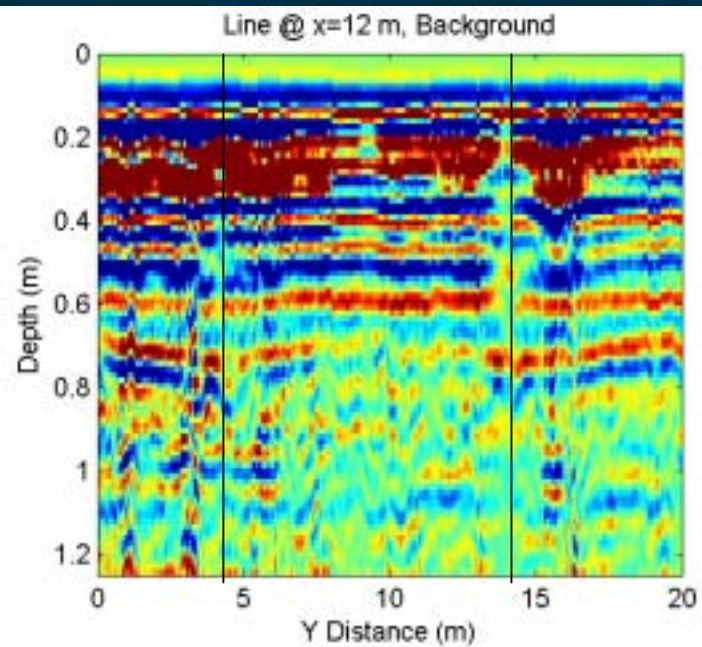
3D survey prior to oil emplacement



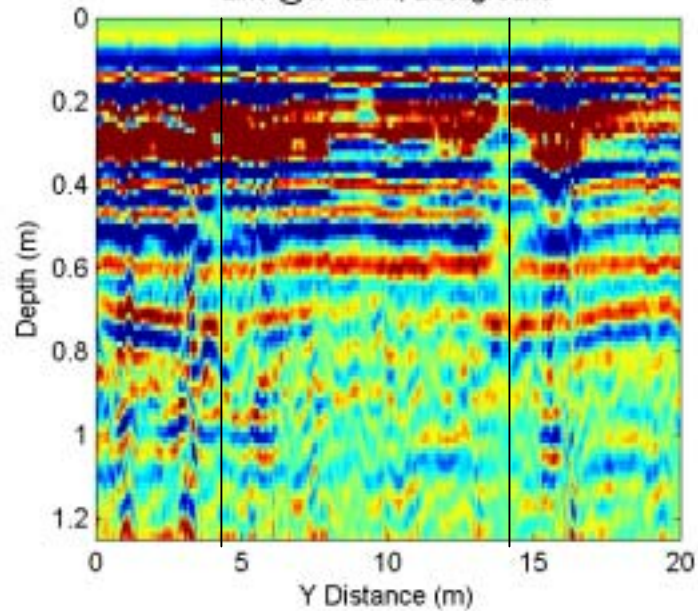
3D survey after oil emplacement



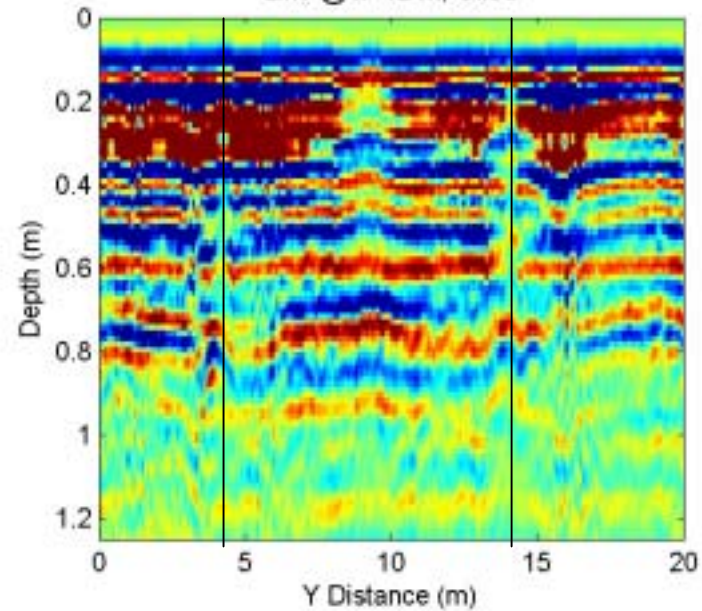




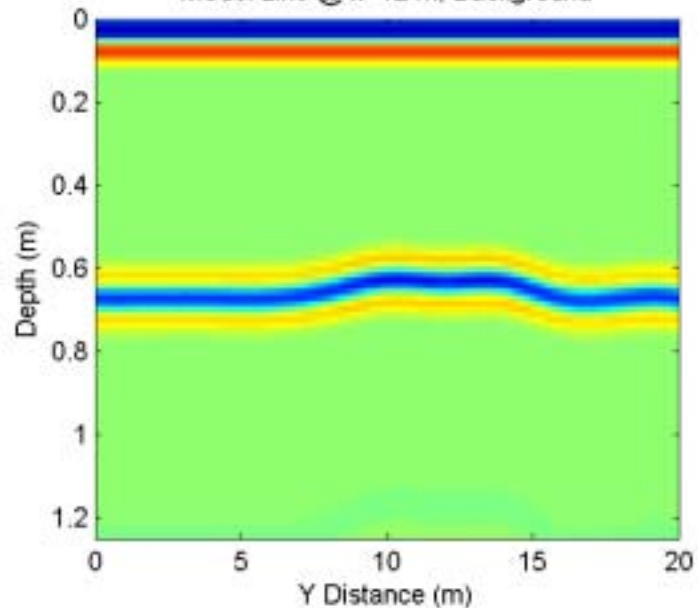
Line @ $x=12$ m, Background



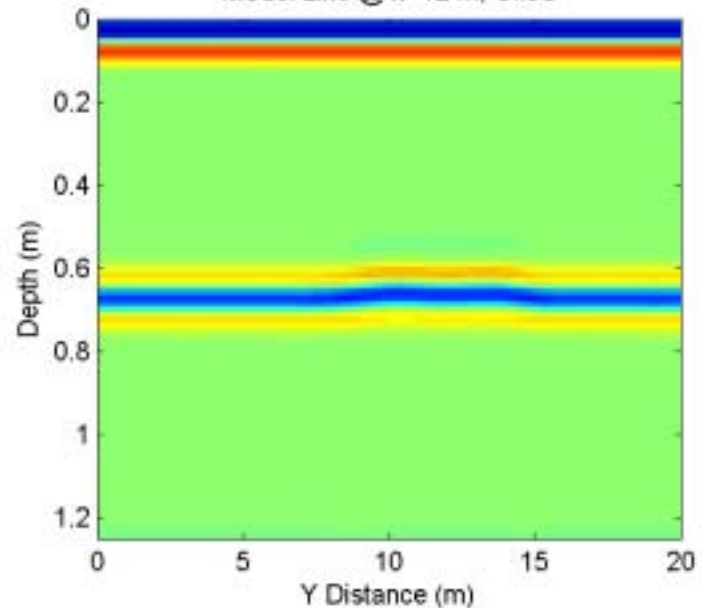
Line @ $x=12$ m, Oiled

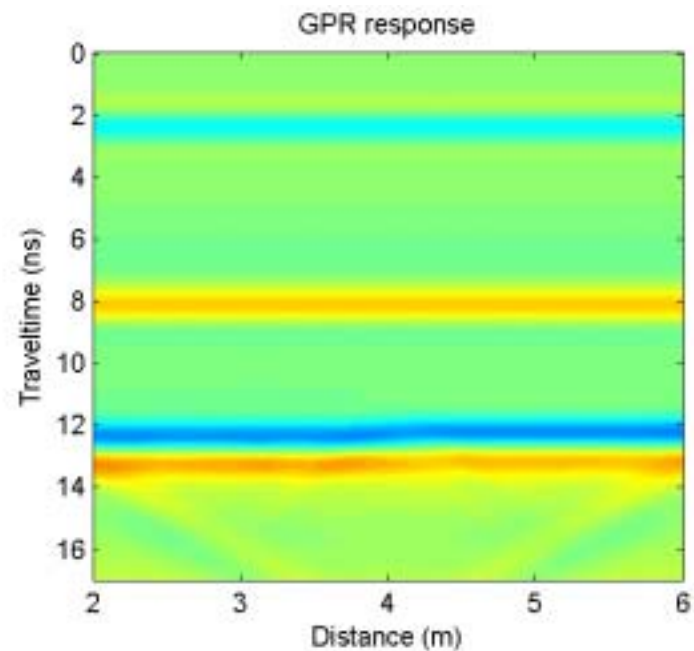
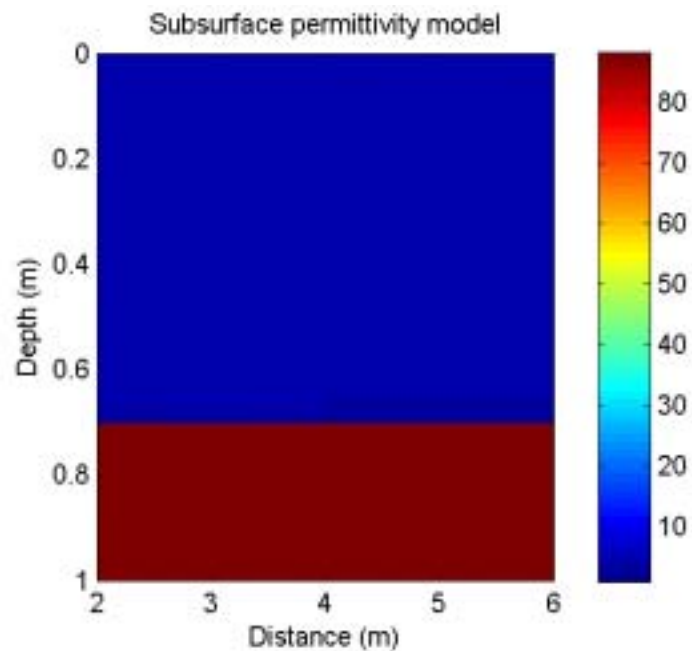
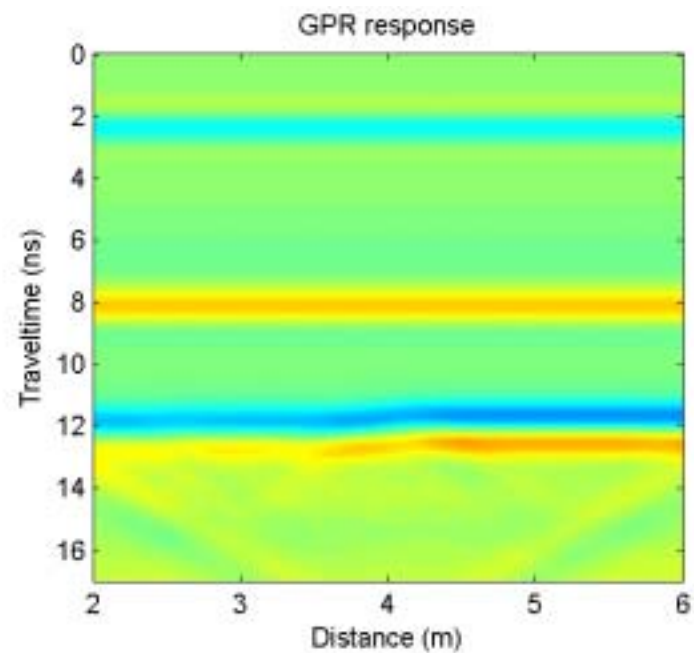
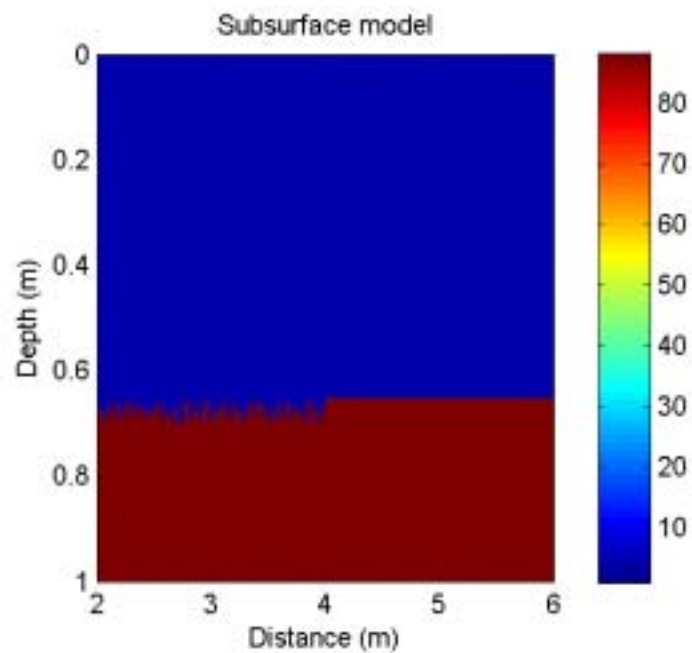


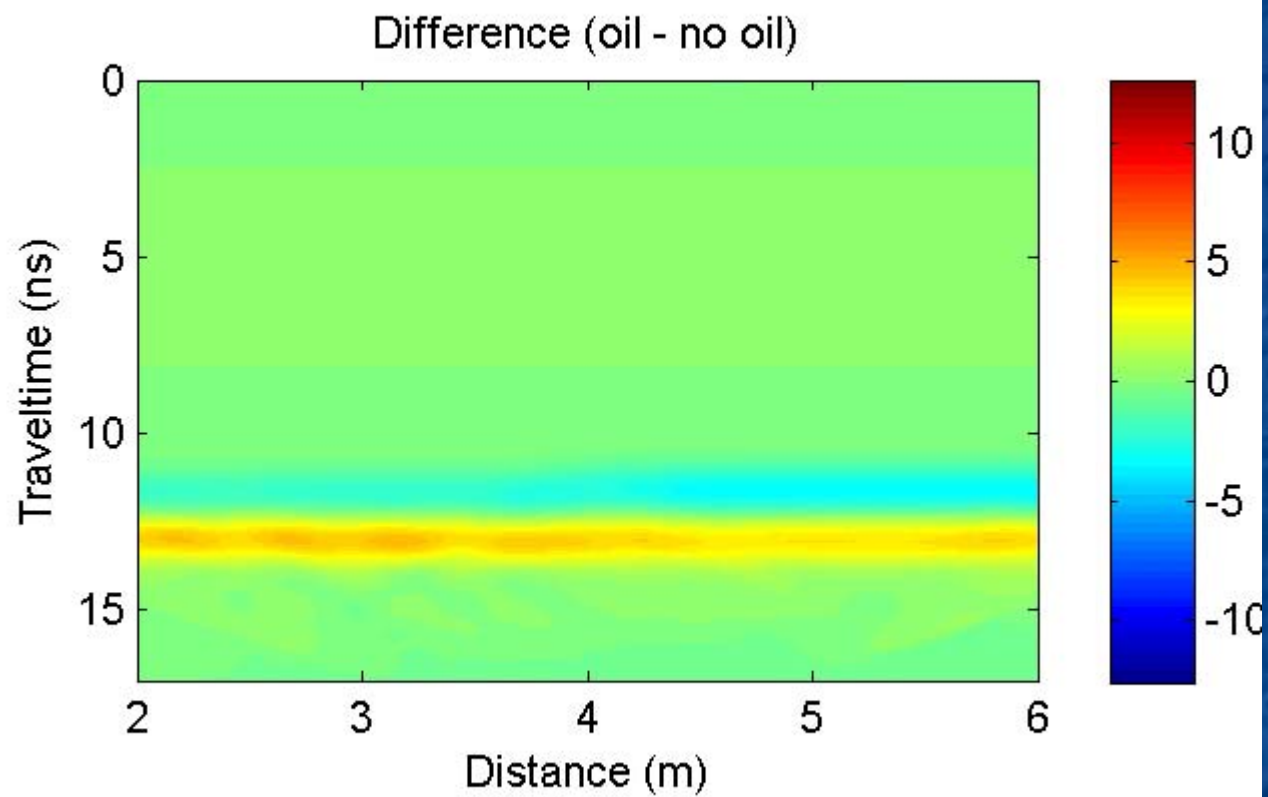
Model Line @ $x=12$ m, Background

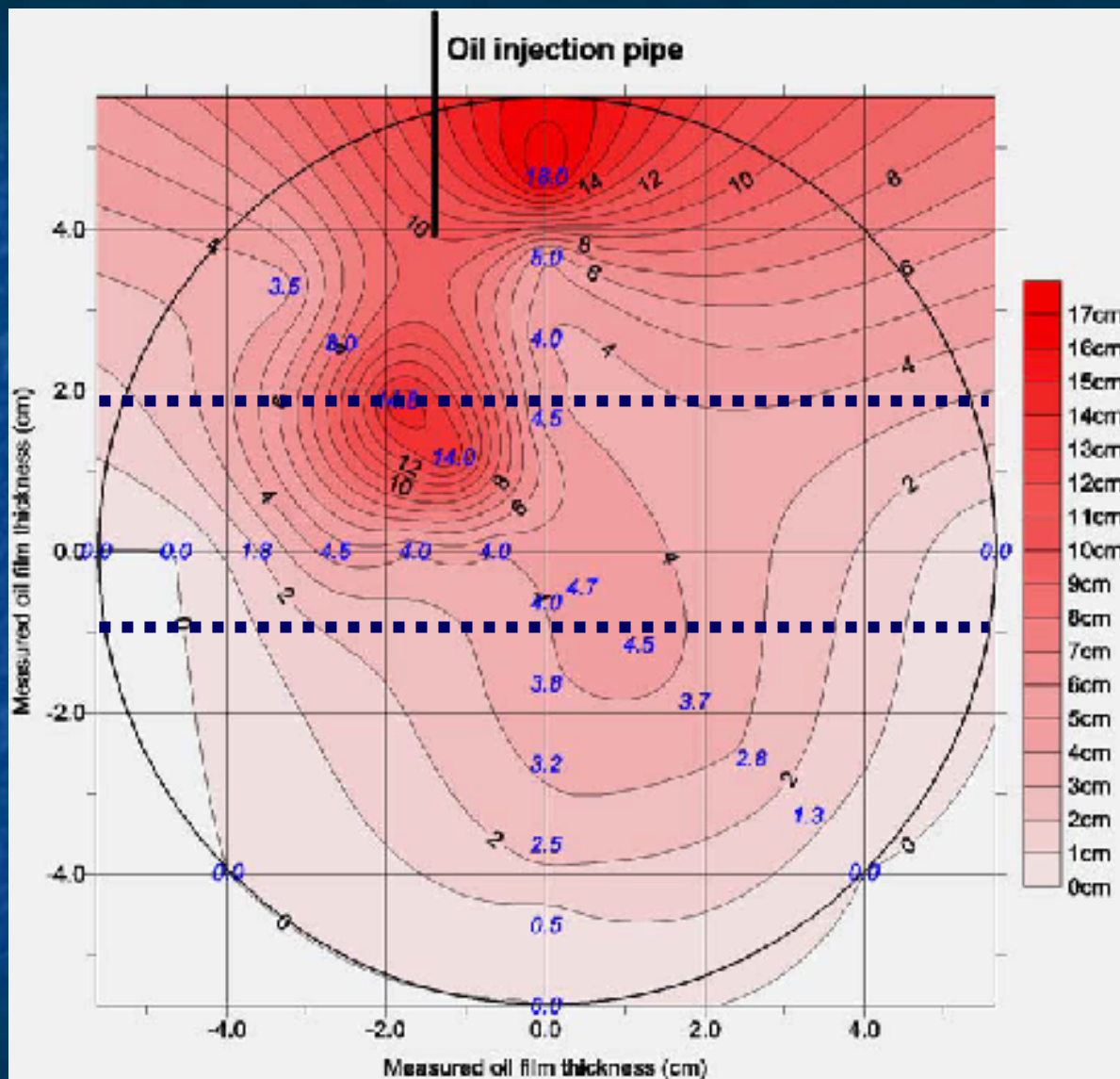


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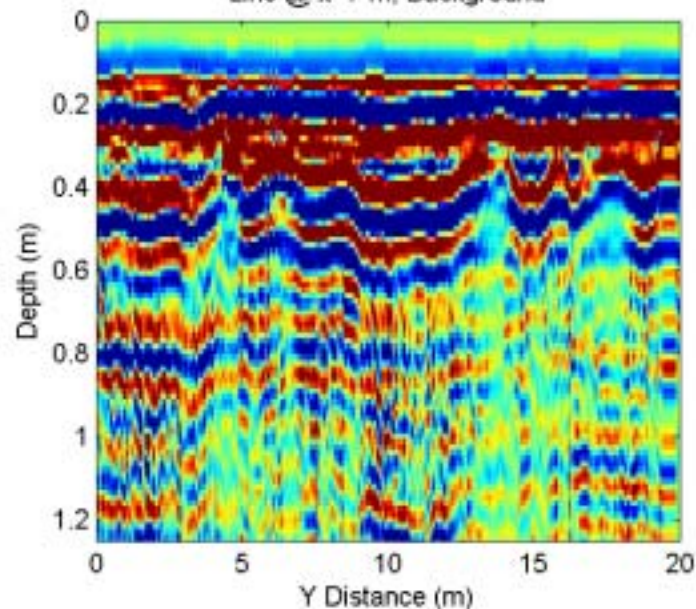




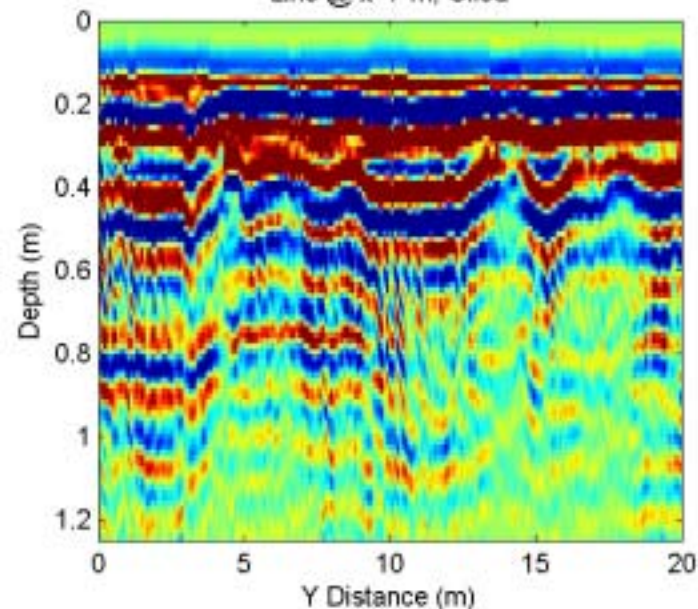




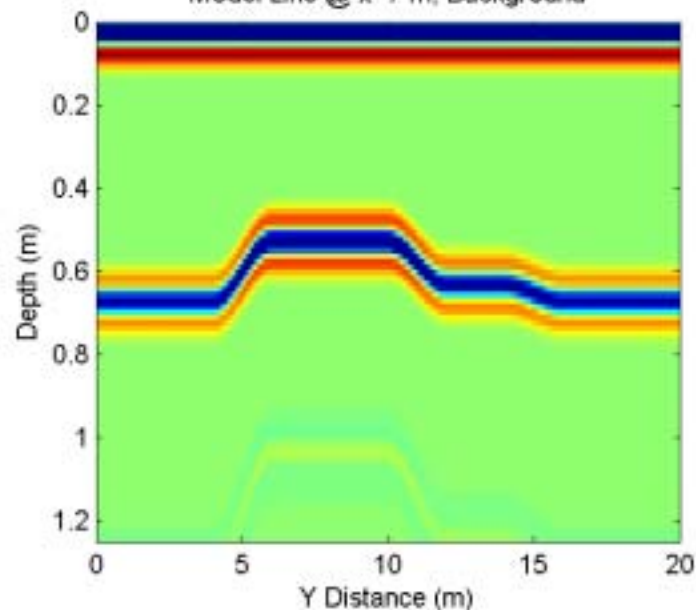
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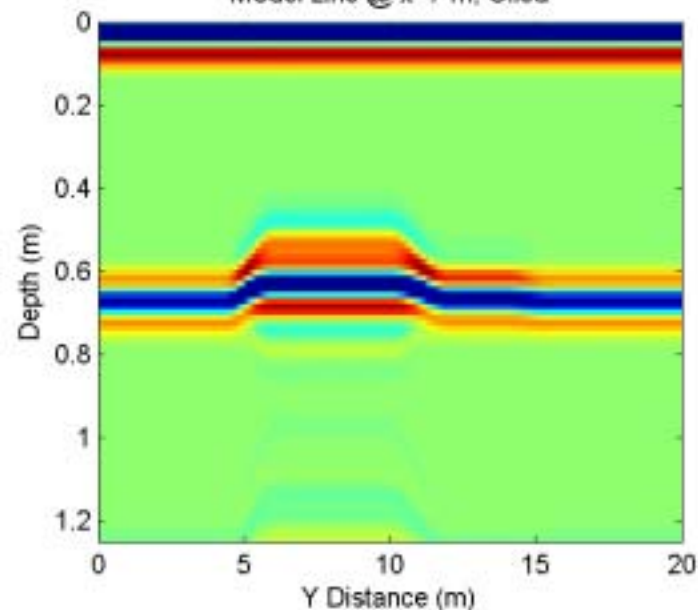
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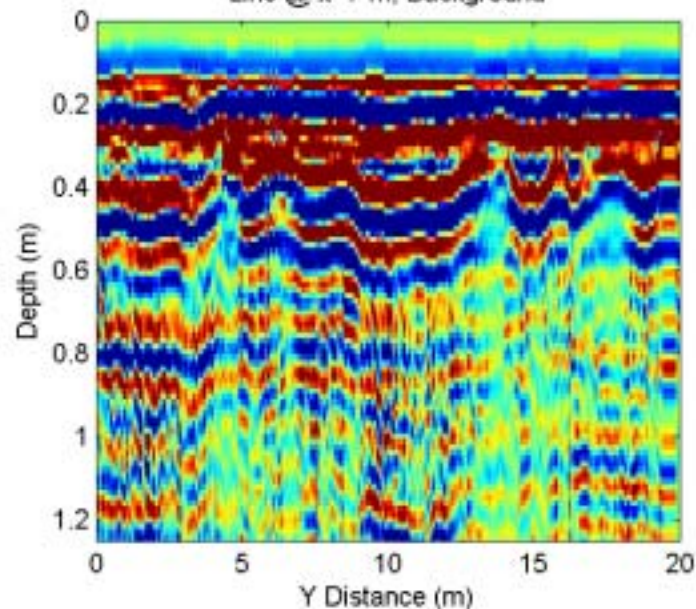
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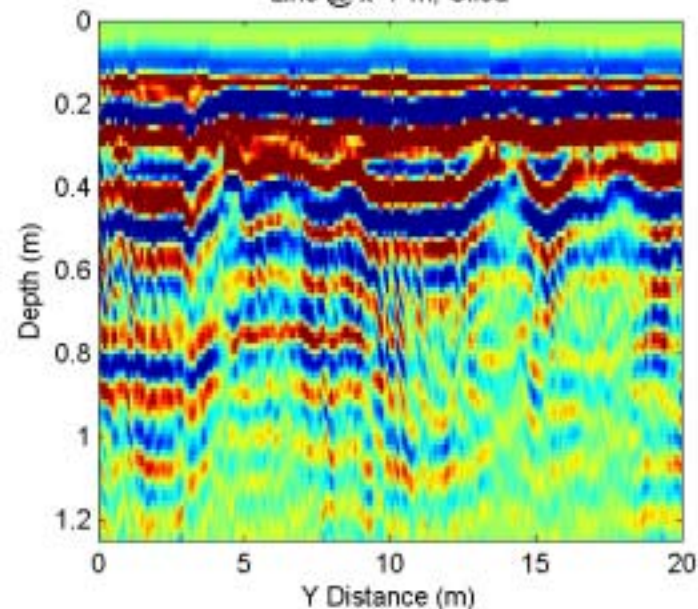
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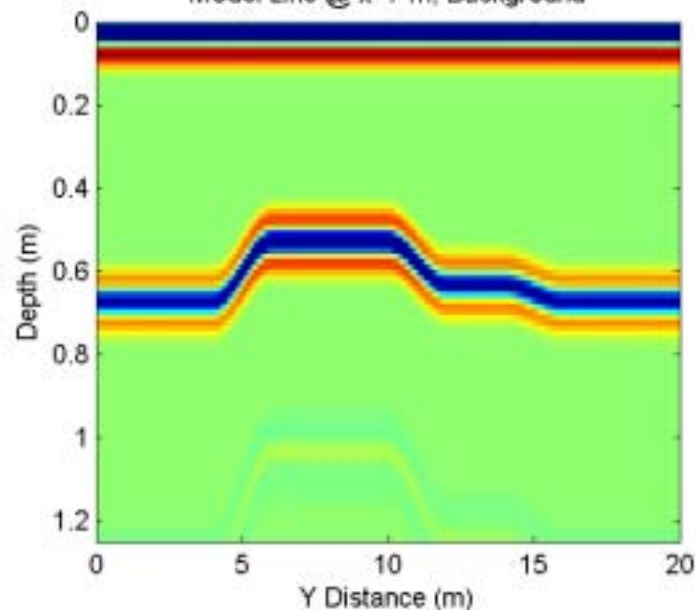
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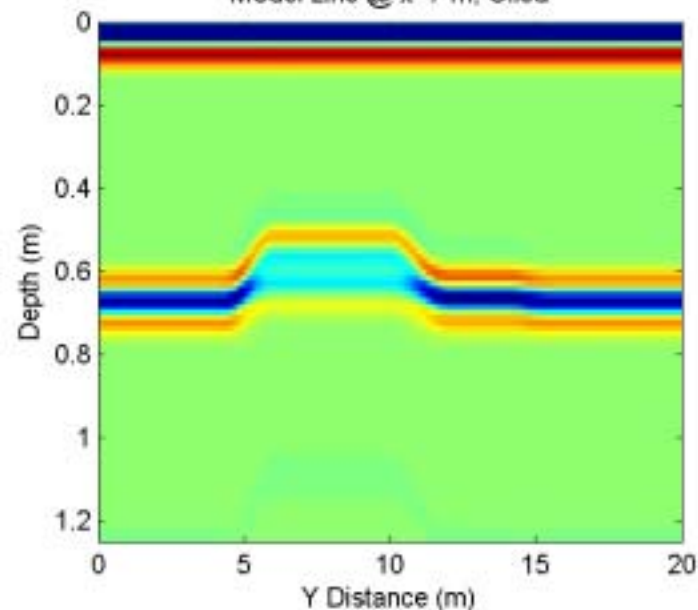
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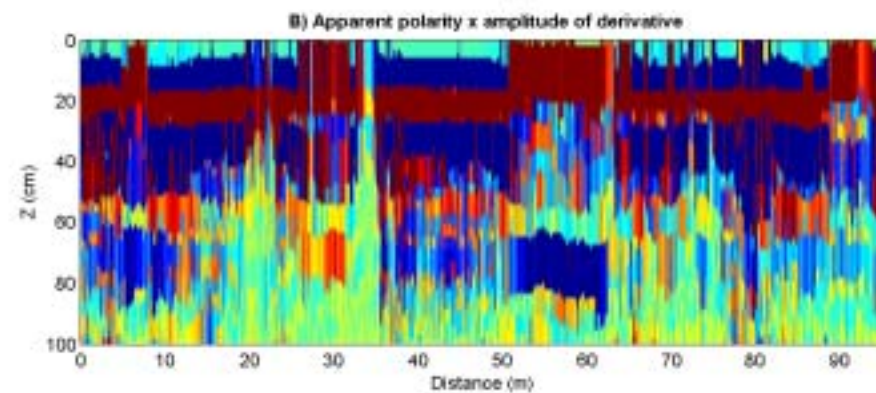
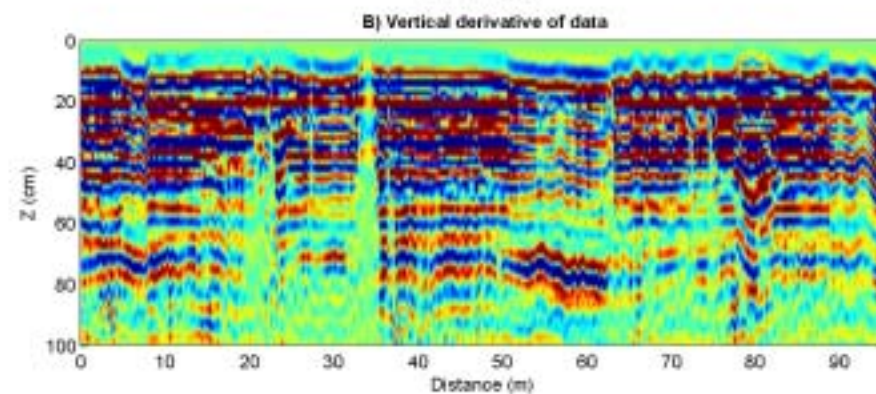
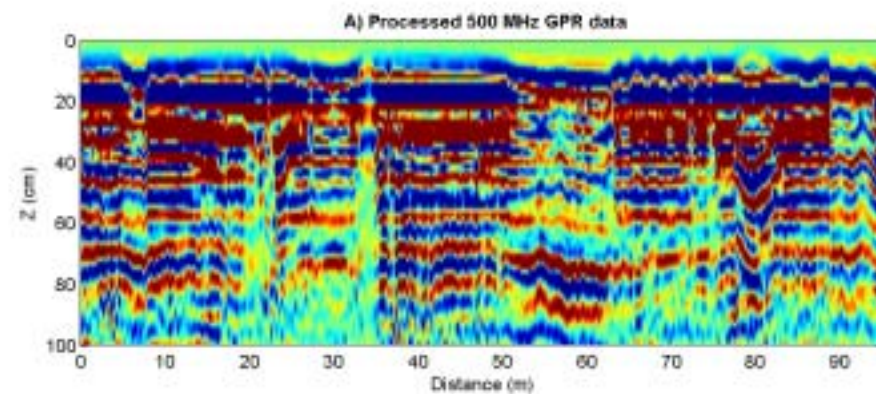


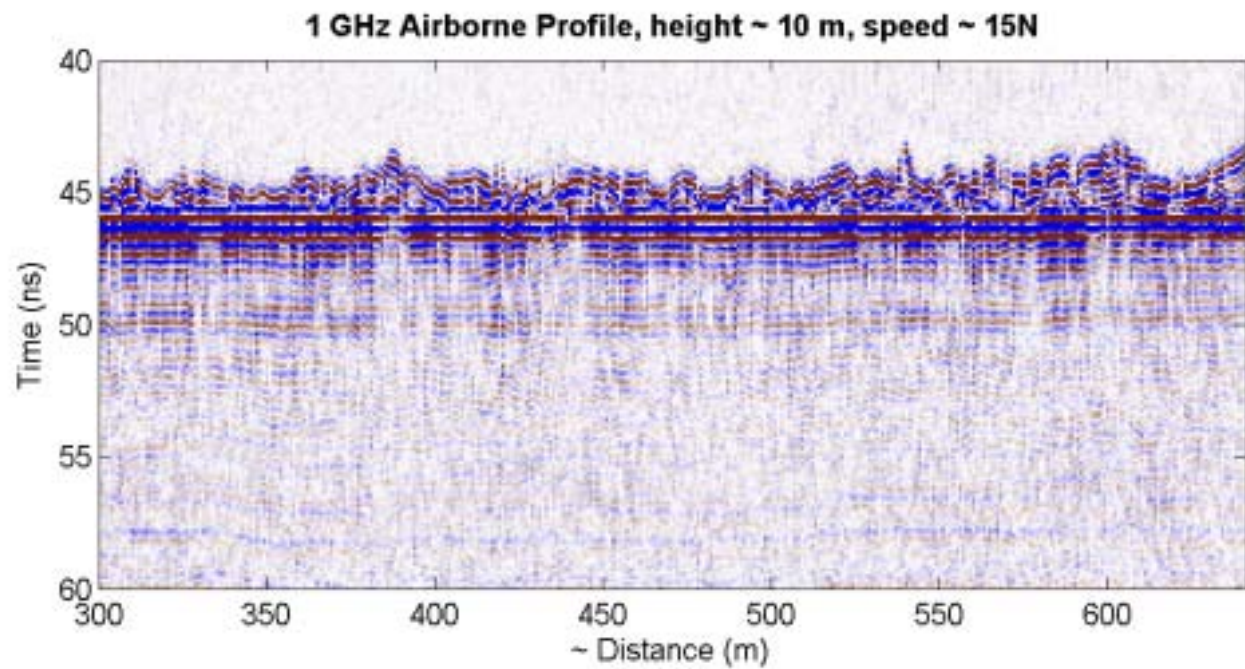
Model Line @ $x=7$ m, Background



Model Line @ $x=7$ m, Oiled







Conclusions

- **Attribute anomalies outlined ~80% of spilled oil**
 - Some false positives
 - Some oiled zones not delineated
- Attribute sensitivity depends on oil thickness, and time since spill
- Results depend on being able to differentiate areas with oil films from the background response, which may be highly variable
- Numerical modeling can help improve our understanding of the GPR response to the oil/ice system
 - Allows for virtual experiments
- Airborne platform has potential